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FOREST PEST MANAGEMENT
Pacific Southwest Region

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BIOLOGICAL EVALUATION OF PESTS AND TREE HAZARDS AT EVANS FLAT CAMPGROUND, GREENHORN RANGER DISTRICT, SEQUOIA NATIONAL FOREST

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ABSTRACT

An entomologist and pathologist evaluated pest conditions and tree hazards at Evans Flat Campground to assist in planning for the Flat Timber Sale in 1988. Within the campground, site class is at least Dunning II, but two common disease pests -- western dwarf mistletoe and annosus root disease -- are weakening pines and firs and predisposing them to insect attack. Hazardous trees, though few, are located on a map, and the pests, including dwarf mistletoe, Fomes annosus, Elytroderma disease, and fir true mistletoe, are described. Management alternatives include continuing current management direction, dwarf mistletoe, fir true mistletoe, and annosus root disease management, hazardous tree treatment, and vegetation management.

INTRODUCTION

Evans Flat is one of only two campgrounds in the Greenhorn Mountains portion of the District currently maintained as developed sites. Major improvements were planned in 1961, but never implemented. Today Evans Flat comprises 16 campsites and no further expansion is anticipated, although it may be improved slightly within the next several years. The road through the campground was oiled for the first time in 1985.

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Although timber has not been harvested in the immediate vicinity for at least 20-25 years, the District is planning the Flat Timber Sale for fiscal year 1988. The objectives of this evaluation were to identify high-risk or hazardous trees that could be removed during the Flat Sale, to describe other insect and disease pest conditions that might affect campground management, and to present alternative ways to manage pest-related problems.

On October 15-16, Vogler and Wenz evaluated pests and tree hazards in the campground. They were accompanied both days by District Recreation Technician Chuck Silvis, and were joined at different times by Silviculturist Louis Jump and by Recreation Officer Greg Reynolds.

OBSERVATIONS

The stands at Evans Flat are dominated by scattered old-growth white fir, ponderosa pine, incense-cedar, and a few sugar pine, with an understory of pole- and small sawtimber-size white fir, incense-cedar, and ponderosa pine. Reproduction, where it is present, is mainly white fir and incense-cedar. Black oaks are scattered through the conifer stands, but are fairly common only on the ridge to the north of the campground. In several areas, 70- to 90-year-old firs are the dominant conifers, and these are growing well. Based on measurements taken from trees in these aggregations, the site quality is high (Dunning Site II).

At present, bark and engraver beetle and wood borer activity within the campground is low, and the problems observed were associated primarily with disease organisms. Current mortality is limited to two ponderosa pines attacked by western pine beetle and red turpentine beetle, and several dead white firs attacked by fir engraver. Several groups of large fir stumps were present, indicating past mortality that likely involved a complex of annosus root disease and fir engraver.

Current pest conditions are illustrated in Figure 1 and in the accompanying key, and are summarized in Table 1. Hazardous trees, though few, are located and described in Figure 1 and the key, and are summarized in Table 2.

WESTERN DWARF MISTLETOE

Infected ponderosa pines and small aggregations of infected pines are scattered throughout the campground. Infected overstory pines are also present on the hillsides to the south and west, where they will continue to be a source of mistletoe seed for many years. Infection is severe on some trees in the campground, and several pines with mistletoe have died, often in conjunction with attack by western pine beetle.

ANNOSUS ROOT DISEASE

Fruiting bodies of Fomes annosus were present in eight fir stumps and three pine stumps. Overall, we found four active infection centers,

Table 1. Pest Conditions at Evans Flat Campground, Greenhorn Ranger District, Sequoia National Forest, October 1985.

DISEASE PEST	HOST	MAP OR SITE NOS.
Annosus root disease	WF	Map Nos. 4, 6, 8, 9, 23-25, 27, & 30
	Pine	Map Nos. 20, 29, & 36
Elytroderma disease	PP	Site No. 1 Map No. 1
Fir engraver	WF	Map No. 27
Logging injury	WF	Map No. 33
Red turpentine beetle	PP	Map No. 37
True mistletoe	WF	Map No. 5
Western dwarf mistletoe	PP	Site No. 1 Map Nos. 3, 7, 11, 14, 18, 19, 21, 28, 32, 37, 38, 40, & 41
Western pine beetle	PP	Map No. 3

PP = Ponderosa pine WF = White fir

Table 2. Hazardous Trees at Evans Flat Campground, Greenhorn Ranger District, Sequoia National Forest, October 1985.

TYPE OF HAZARD	HOST	MAP OR SITE NO.
Dead trees	PP	Tree No. 3
	WF	Tree No. 39
Dead, attached limbs	BO	Map Nos. 2, 13, 26, 34, & 35
	PP	Map No. 40
Stem and root decay	WF	Map No. 16
Trees that may become hazardous in future	PP	Map No. 32
	WF	Map No. 36

BO = Black oak PP = Ponderosa pine WF = White fir

comprising stumps and dead or declining trees, all in white fir. These centers are generally devoid of fir reproduction, and may have to be planted with pines and oaks if they are to support trees again.

WHITE FIR TRUE MISTLETOE

One white fir in the campground and several fir on the surrounding hillsides were infected with true mistletoe (Phoradendron bolleanum subsp. pauciflorum). The infected fir in the campground was growing slowly (23 rings per inch in the last decade), but is not presently hazardous. True mistletoe is spread by birds, usually to the tallest trees in a stand, and is seldom a threat to understory firs. In stands that are increasingly dominated by white fir, however, the parasite may become more widespread and injurious.

ELYTRODERMA DISEASE

This perennial needle-cast fungus was observed near campsites No. 1 and No. 4, and is present on pines around the meadow northwest of the campground. Generally, the disease does not cause significant damage until 40 percent or more of the crown is infected. At Evans Flat, infection was below this threshold.

BARK AND ENGRAVER BEETLES

Bark beetle activity in the campground is currently low, but should be considered in any management plans. Two beetles are likely to be important at Evans Flat: the western pine beetle (Dendroctonus brevicomis) in ponderosa pine, and the fir engraver (Scolytus ventralis) in true fir.

LOGGING INJURY

Three white firs at Site No. 4 and scattered pines and firs elsewhere showed evidence of stem injury caused by logging, tree removal, or construction. Such damage can lead to extensive decay in true firs, particularly in firs damaged at ground level. Tree vigor and longevity can be reduced, and hazard increased, if steps are not taken to prevent stem damage during logging operations.

TREE HAZARDS

Three trees in the campground were hazardous and should be removed for safety: one had extensive stem decay (Map No. 16) and two were dead (Map Nos. 3 and 39). Potentially hazardous dead limbs were noted on five black oaks and one ponderosa pine, and should be removed. In addition, one pine and one fir had defects or potential defects that should be checked periodically to see whether they pose any hazard to people or property in the future.

MANAGEMENT ALTERNATIVES

The following pest, tree hazard, and vegetation management alternatives are not mutually exclusive and may be implemented in any combination. Biologies of the major pest organisms are included at the end of this report.

CONTINUE CURRENT MANAGEMENT

Current vegetation management at Evans Flat consists primarily of periodic removal of obviously hazardous trees and limbs, and of dead, usually bark beetle-killed, trees. Under this alternative, existing annosus root disease centers will increase in size through root contacts, and new centers will develop as recently dead and hazardous conifers are cut, exposing fresh stump surfaces to spore infection (assuming no borax is used). Similarly, dwarf mistletoe infection will slowly intensify within already-infected pines and spread to healthy trees. Elytroderma disease may spread and intensify during wave years; under favorable climatic conditions, infection can become severe enough to predispose weakened pines to bark beetle attack.

Taken together, these stresses will increase the probability of western pine beetle and fir engraver attack. Pine and white fir mortality will likely increase over the next two decades, and will be greater than if no pest management action is implemented. Mortality will be even higher if an additional stress such as a drought occurs. Such mortality will result in understocked areas in the campground, ever larger openings, and loss of desirable individual trees. Furthermore, as campground trees (white fir and black oak, in particular) age, decline, and decay, their risk of failure will increase.

MANAGE DWARF MISTLETOE INFESTATIONS

The progressive effects of dwarf mistletoe are not dramatic or immediately obvious to the casual observer, but take place over many years. Field studies in recreation areas have shown that pines with dwarf mistletoe ratings of 1 through 4 will normally advance to the next higher class in about 10 years, while trees with ratings of 5 or 6 are prime targets for bark beetle attack and will probably be killed in the next 10 to 15 years. Removal of all mistletoe infections should allow a tree to reach normal maturity, and removal of just witches' brooms from a moderately-infected tree may increase its life by 10 to 20 years.

Dwarf mistletoe treatments may include any combination of the following actions:

1. Removing infected overstory trees to protect regeneration.

2. Removing witches' brooms to prolong tree life.

3. Removing all infections by pruning to eliminate the parasite.

4. Removing severely-infected trees that cannot be successfully pruned.

5. Thinning to remove infected trees and release residual trees.

6. Destroying severely-infected stands or aggregations and then regenerating.

7. Creating buffer strips to prevent re-entry of dwarf mistletoe.

8. Favoring or planting resistant species.

More detailed guidelines for planning and carrying out a mistletoe control project are available from FPM on request. Before deciding which of the above control treatments are suitable for Evans Flat, the District must rate the severity of infection of all ponderosa pines within the affected aggregations. Only after the scope of the control job is assessed tree-by-tree can the choice be made between eliminating the parasite -- which, in some situations, may result in severe understocking or complete destruction of a stand -- or reducing the severity of infection to a level that the trees can live with. Often, dwarf mistletoe can be eliminated from all or a portion of a campground, but only after two or more re-treatments. Another approach is to isolate campground pines from outside infection sources with a buffer strip, and then to treat infected aggregations within the campground according to the severity of infection and the value of the individual infected trees, selecting branch pruning, witches' broom removal, thinning, or other options as appropriate.

REMOVE TRUE MISTLETOE-INFECTED WHITE FIR

True mistletoe is not presently a problem at Evans Flat. In stands where white fir is dominant, however, the disease can infect trees of all sizes, sometimes causing infections low in the crown. The condition is not uncommon in white fir stands in southern California, and a few severe infestations can be found on the Sequoia also. Since few firs in and around Evans Flat are infected, it would be wise to remove them during the Flat Sale to prevent future disease problems.

REDUCE IMPACT OF ANNOSUS ROOT DISEASE

In openings caused by tree mortality from annosus decay, plant a mixture of pine and incense-cedar, or pine alone. Pines are usually not susceptible to infection originating in true fir stumps, and the number of infected pine stumps is so small (three) that the disease does not appear to be an important threat to pines. However, the District should closely monitor any pine mortality that appears associated with the infected pine stumps shown on the Map. While pine stump infections have so far not resulted in pine mortality, they could create pine infection centers in the futue.

Some firs planted in annosus-caused openings may succumb to the disease, but most will withstand infection once they attain rapid growth; the susceptibility of incense-cedar to annosus from fir stumps is not known, but cedars should also be able to withstand infection if they are growing well. Most hardwoods, including black oak, are resistant to annosus root disease and, if suitable for the site, can be planted in infection centers.

While removing hazardous and diseased trees, avoid injuring residual conifers, particularly true firs; basal wounds are an important entry court for decay fungi. Treat all fresh conifer stumps with borax to minimize new annosus root disease infection (FSM 2305 and 2331.33, R-5 Supplement No. 90).

DEVELOP A TREE HAZARD MANAGEMENT PLAN

Current hazardous tree management -- consisting of removing obviously defective and dead trees and tree parts that pose a serious threat to visitors and their possessions -- is a minimal requirement of good campground management. Beyond this, however, it would be beneficial to develop and implement a tree hazard management plan for systematically evaluating Evans Flat and other District campgrounds. Such a plan would enable the District to detect developing tree hazards, evaluate past tree hazard management actions, improve future efforts, develop an efficient record-keeping system, and provide for continuity in spite of personnel changes. A systematic hazard evaluation plan is consistent with FSM 2332.1 and should include four elements:

Regular Inspection. Tree hazard evaluation must be done on a regular schedule, preferably once a year in the spring.

Records of Hazard Ratings. Inspectors should keep written records of tree species and size, defects, pests, hazard rating, and control decision for each tree evaluated; tag the trees that are to be monitored or removed; and map the trees in relation to structures, campsites, and roads. Written records will make it possible for new inspectors to evaluate sites without having to start from scratch.

Records of Tree Failures. Recording tree failures, their causes, and associated damage will enable recreation site managers to develop a history of the types of failures peculiar to their site, and help them evaluate future failure potential. Failure records also provide a check on the effectiveness of hazard tree removal guidelines; repeated failures may indicate that trees rated marginally-safe must be removed in future.

Trained Inspectors. Inspectors should develop and maintain expertise in hazardous tree management through training and field experience. Opportunities include the Hazard Tree Recognition and Recreation-Oriented Pest Management course offered annually by FPM, as well as other seminars that emphasize tree care and management in developed sites.

Inspectors should also build up their on-the-ground experience in the hazards peculiar to their District's forest stand and site conditions.

If requested, FPM will assist the District in setting up a tree hazard evaluation program.

MANAGE THE VEGETATION

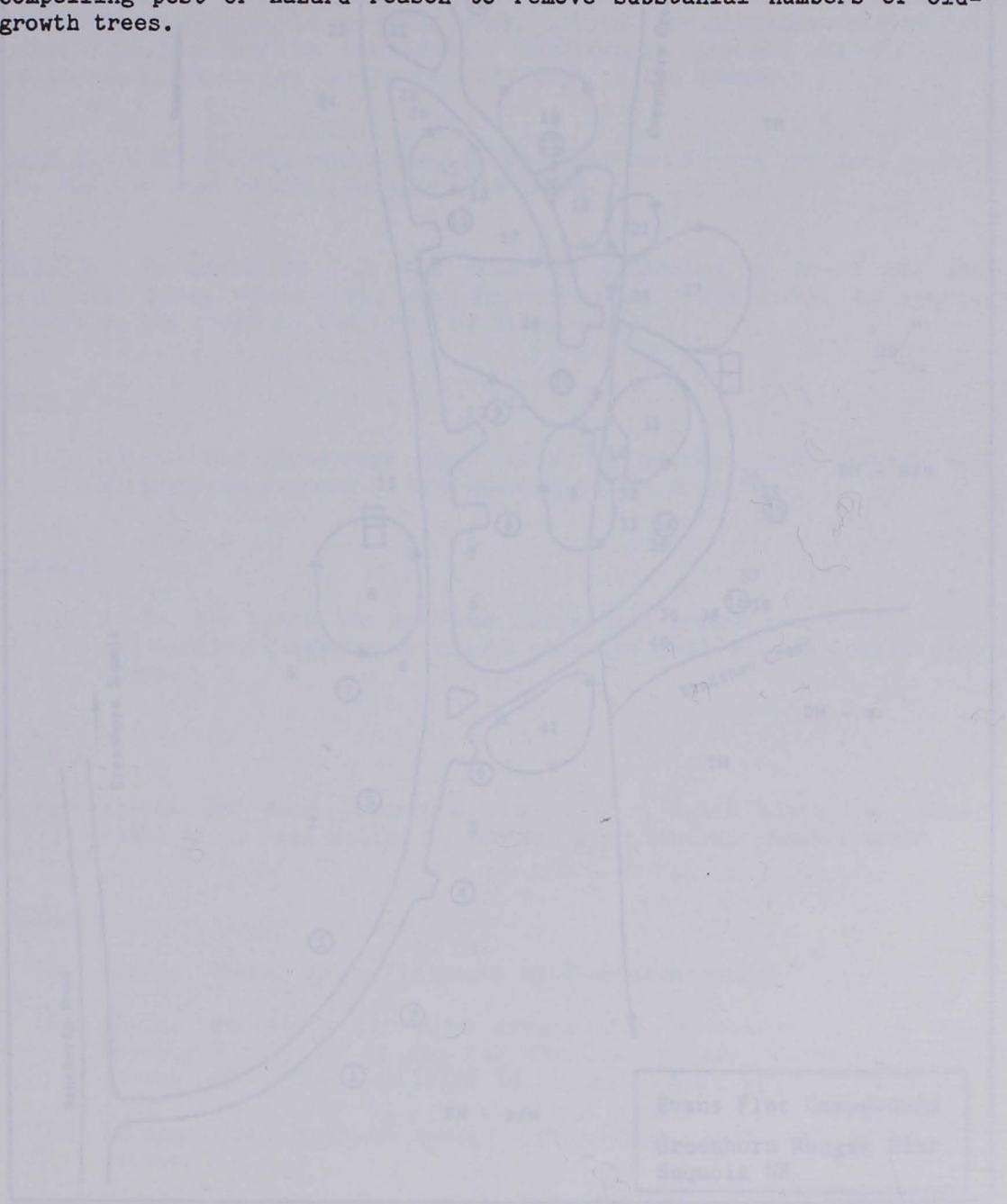
In addition to treating pests and hazard trees, it may be wise to thin overstocked aggregations and to plant those that are understocked or stocked with genera susceptible to disease. Overstocked conditions, as near Site 11, may result in reduced growth rates, and can contribute to stressed conditions that predispose trees to bark beetle attack. Large old-growth firs, although likely to live for several decades more, will not occupy the site forever. Hence, it is advisable to plan now for their replacements. Maintaining healthy, rapidly-growing, and mixed-species stands, where possible, is the best insurance against stand decline and subsequent bark beetle and fir engraver attack.

All local conifers and black oak may be planted, except where host-specific disease conditions will make success difficult. Wherever ponderosa pines are planted, the adjacent pines should be treated for mistletoe to protect the young trees from infection. Sugar pine may be planted, as it is not susceptible to western dwarf mistletoe, but planting rust-resistant stock is advisable because of the presence of white pine blister rust in the Greenhorn Mountains. To improve regeneration success, involve the public in the care and protection of planted trees; without their help, many saplings will be needlessly damaged or destroyed.

REMOVING THE OLD-GROWTH. The District expressed interest in removing much of the high-volume old-growth from the campground and surrounding stands during the 1988 Flat Timber Sale. Outside the campground, several dwarf mistletoe-infected ponderosa pines are seed sources for spread of the parasite into campground trees, and these can be removed if they are within range of the campground pines (generally, a distance equal to the height of the highest mistletoe plant in the infected overstory). Elsewhere some of the large white fir have extensive true mistletoe infection in their tops; these should removed to forestall future problems with the disease. Many older firs are growing slowly and may die within the next few decades, but at present most were not judged to pose an appreciable hazard to people or property within the campground.

Within the campground, removal of large numbers of old-growth trees, although it may speed the revitalization of the stand, can result in excessive damage to residuals, particularly to true firs. Removing even selected large trees can cause damage to residuals and to regeneration if care is not taken to protect them. If campground old-growth is included in the Flat Sale, special provisions to protect campground vegetation should be incorporated into the contract.

Furthermore, old-growth trees are a part of the character of the campground, even though some are slow-growing and decadent, and should only be removed if they are a disease threat to adjacent trees, or if they are a hazard to people or property. At present, there is no compelling pest or hazard reason to remove substanial numbers of old-growth trees.



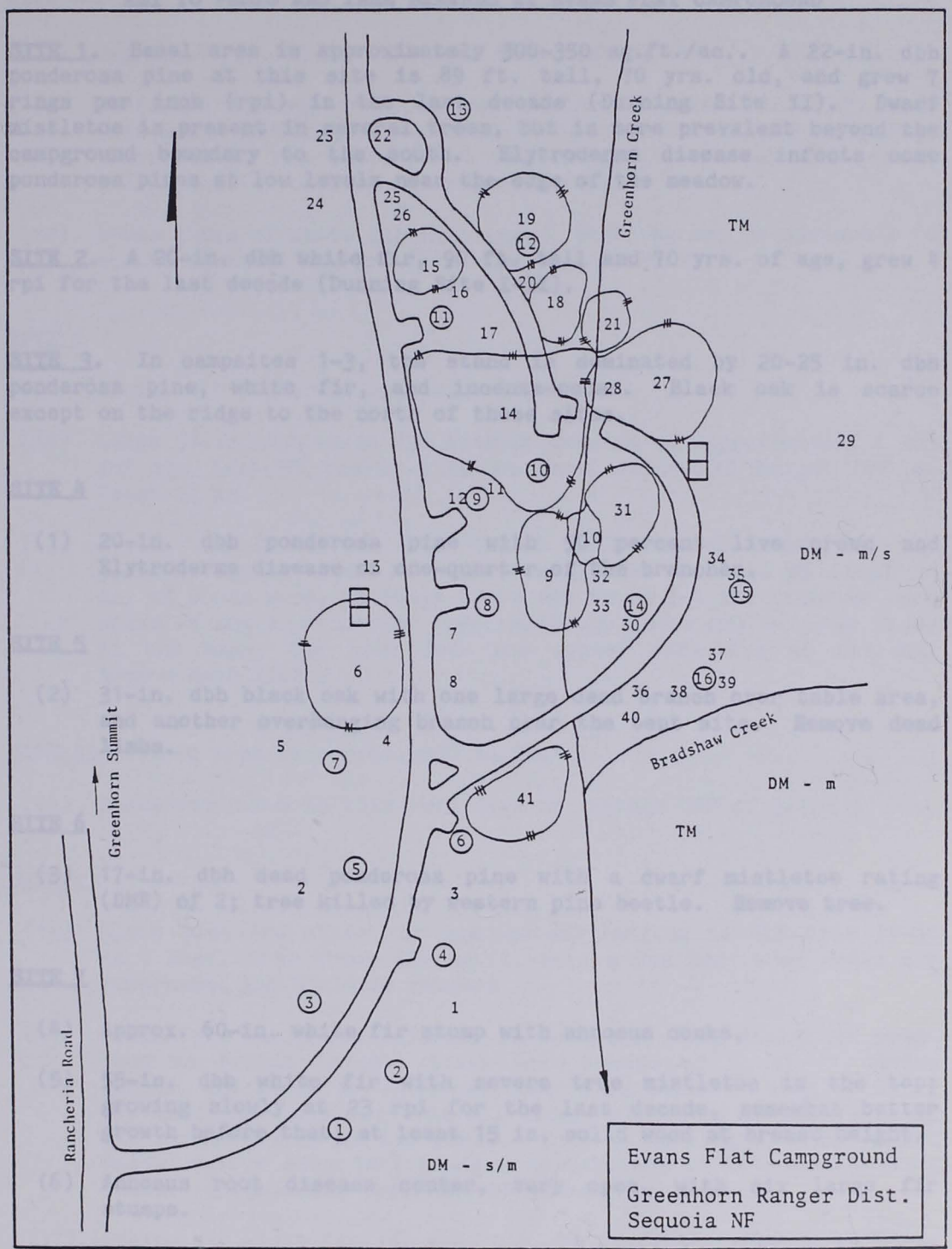


Figure 1. Insect and disease pests and hazardous tree conditions at Evans Flat Campground, October 1985. (Campsite numbers are shown in circles; uncircled numbers refer to pest conditions in the Key. TM = true mistletoe; DM = dwarf mistletoe; s/m = slight-to-moderate infection, m = moderate infection, and m/s = moderate-to-severe infection).

KEY TO PESTS AND TREE HAZARDS AT EVANS FLAT CAMPGROUND

SITE 1. Basal area is approximately 300-350 sq.ft./ac.. A 22-in. dbh ponderosa pine at this site is 89 ft. tall, 70 yrs. old, and grew 7 rings per inch (rpi) in the last decade (Dunning Site II). Dwarf mistletoe is present in several trees, but is more prevalent beyond the campground boundary to the south. Elytroderma disease infects some ponderosa pines at low levels near the edge of the meadow.

SITE 2. A 20-in. dbh white fir, 90 ft. tall and 70 yrs. of age, grew 4 rpi for the last decade (Dunning Site I-II).

SITE 3. In campsites 1-3, the stand is dominated by 20-25 in. dbh ponderosa pine, white fir, and incense-cedar. Black oak is scarce except on the ridge to the north of these sites.

SITE 4

(1) 20-in. dbh ponderosa pine with 50 percent live crown and Elytroderma disease on one-quarter of the branches.

SITE 5

(2) 31-in. dbh black oak with one large dead branch over table area, and another overhanging branch near the tent site. **Remove dead limbs.**

SITE 6

(3) 17-in. dbh dead ponderosa pine with a dwarf mistletoe rating (DMR) of 2; tree killed by western pine beetle. **Remove tree.**

SITE 7

(4) Approx. 60-in. white fir stump with annosus conks.

(5) 55-in. dbh white fir with severe true mistletoe in the top; growing slowly at 23 rpi for the last decade, somewhat better growth before that; at least 15 in. solid wood at breast height.

(6) Annosus root disease center, very open, with six large fir stumps.

SITE 8

(7) Ponderosa pine with DMR of 3-4.

SITE 8 (Cont.)

(8) Approx. 60-in. white fir stump with annosus conk.

(9) Confirmed annosus root disease center in white fir, very open from past mortality. Three 10-14 in. dbh white firs are still alive within the center, but have ragged crowns and flat tops, and may be infected by annosus root decay.

(10) Dense patch of white fir seedlings. Thinning may be advisable to ensure survival and growth of the desired trees.

SITE 9

(11) 28-in. dbh ponderosa pine with a DMR of 6.

(12) Large 36-in. dbh white fir with an average of approximately 6 rpi for the last 50 years; stem is sound at breast height for at least 12 in.

(13) 27-in. dbh black oak near toilet with several dead, 4-6 in. diameter limbs. Stem at breast height on west has at least 12 in. of sound wood, although there are three 2-4 in. diameter open holes at the base of the tree; although there may be some decay at the base, the tree does not appear defective at present. **Remove dead limbs.**

SITE 10. Basal area is approx. 300 sq.ft./ac.

(14) Ponderosa pines in this area have an average DMR of 3-4.

SITE 11

(15) Mixed pine and white fir aggregation ranging in dbh from 15-35 in., basal area about 450 sq.ft./ac.; a few scattered trees are suppressed and could be removed.

(16) 28-in. dbh white fir adjacent to tent pad; four inches of sound wood at breast height; lower bole sweeps up to 15 ft. above ground, and leans to northeast; four bird holes in stem up to 20 ft. indicate extensive internal decay; stem dead to one-fifth of its circumference on the south. Tree is defective, with rodent holes at the base indicating a possibility of hollowed, rotted roots. **Potentially hazardous tree; remove.**

(17) 24-in. dbh white fir, 93 yrs. old, 96 ft. tall, growing at 8 rpi (Dunning Site II).

SITE 12. Basal area is approx. 240 sq.ft./ac.

(18) Four ponderosa pine, DMR 3-5; one 12-in. dbh sugar pine without dwarf mistletoe.

(19) Six ponderosa pine, ranging in dbh from 15-30 in., five infected with DMRs of 3-6, one (24-in. dbh) uninfected.

(20) 30-in. pine stump has several annosus conks; adjacent white fir is thinning and may be infected.

(21) Four stunted ponderosa pine with average dbh of about 12 in. , and average DMRs of 5-6.

SITE 13

(22) 24-in. dbh white fir, 89 ft. tall, about 65 yrs. old, growing five rings per inch (rpi) in the last decade (Dunning Site I). Surrounding area is comprised mainly of 18-24 in. dbh white fir and ponderosa pine with a basal area of 180 sq. ft./ac.

(23) Annosus conks in white fir stump.

(24) Annosus conks in 40-50 in. white fir stump.

(25) Annosus conks in 40-50 in. white fir stump.

(26) 41-in dbh black oak with broken and dead 4-6 in. diameter branches that should be pruned. 18 in. diameter broken stob on the south side of tree with two dead side branches -- should be trimmed and checked for extent of decay. Open wound on the southwest side at 12 ft. below the first major branch fork, comprising one-fifth of the circumference of the tree -- check periodically. Tree has at least 12 in. sound wood at dbh. **Remove and trim dead limbs and stobs.**

ACROSS CREEK FROM SITE 10

(27) A group of 8-10 white fir stumps with annosus conks confirmed. A true root disease center with several standing dead or dying firs and at least one declining 18-in. dbh white with probable fir engraver attacks in the top.

(28) Three large ponderosa pine with DMRs of 3-5.

(29) Well-rotted ponderosa pine stump with large conks of Fomes annosus.

SITE 14

(30) 40-in. white fir stump with annosus conks.

(31) Many 16-35 in. dbh white firs, basal area 560 sq.ft./ac.. Thinning is a possibility, but take care to avoid damage to stems of residual firs (see comment No. 33, below).

(32) 53-in. dbh ponderosa pine with a tight fork at 65 ft. above ground, several 6-8 in. diameter dead limbs; a second, weaker fork is oriented toward the northwest, away from site 14; another tight fork is visible about 95 ft. above ground; DMR is 2. **Observe tree for increased defect over time, or for changes in visitor use patterns beneath the tree.**

(33) Three white fir with logging scars that may have decay behind them; tops are flattened.

SITE 15

(34) Two black oaks with dead limbs in opening around toilet between campsites 14 and 15. **Remove dead limbs.**

(35) Four black oaks with dead limbs overhanging the campsite. **Remove dead limbs.**

SITE 16

(36) 31-in. dbh white fir leaning to the east, with a ragged crown, flat top, and growing at 19 rpi; adjacent pine stump is infected with annosus root decay. **Observe tree for root uplift, or any change in amount of lean.**

(37) Dying 27-in. dbh ponderosa pine with a DMR of 6, signs of red turpentine beetle attack at the base. **Remove soon or shortly after death.**

(38) 21-in. dbh ponderosa pine, DMR 6.

(39) 27-in. dbh dead white fir. **Remove.**

(40) 42-in. dbh ponderosa pine with large dead limbs, DMR 5; crown is ragged, live crown about 25%; tree is close to road and may pose some hazard to vehicles or pedestrians. **Remove dead limbs.**

BETWEEN SITES 6 AND 16

(41) Group of ponderosa pines with an average DMR of 4-5.

APPENDIX: BIOLOGY OF MAJOR PEST ORGANISMS

ANNOSUS ROOT DISEASE OF TRUE FIR

Fomes annosus is a fungus that attacks a wide variety of woody plants, including all western conifers. Some hardwoods and brush species are affected also, among them Pacific madrone, manzanita, and bitterbrush, but most are immune to infection. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is greater in old growth true fir stands and in stands with basal areas over about 330 square feet/acre.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly-cut stump surfaces or wounds on living trees. The fungus then spreads via root contacts into the root systems of adjacent live trees. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, F. annosus grows through root cambial tissue into the root crown where it girdles and kills trees within a few years. In less resinous species such as true firs, the fungus sometimes kills trees, but is usually confined to the heartwood and inner sapwood of the larger roots where, it causes butt and root decay and chronic growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness.

Losses in true fir from F. annosus are mainly the result of windthrow resulting from root decay, and damaged root systems, which predispose trees to attack by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But, when true firs slow in growth because of stand or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before a tree dies.

In general, annosus root disease can spread from the roots of pine to true fir roots, but is rarely observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, F. annosus is commonly found only on true fir and both species seldom die within a single infection center.

ELYTRODERMA DISEASE

The fungus Elytroderma deformans causes the most serious needle disease of ponderosa and Jeffrey pines in California. Occasional hosts include lodgepole, knobcone, Coulter, and pinyon pines. Unlike other needle

diseases, Elytroderma infects twigs and branches systemically, allowing continued reinfection of a host's new needles even under adverse environmental conditions. Elytroderma impact is most severe in recreation forests, where the unsightly appearance of infected trees and occasional mortality can degrade the appearance and health of a stand.

Fungal fruiting bodies (hysterothecia) release spores from infected needles in late summer and early fall. Spores are windborne to susceptible hosts and, if environmental conditions are suitable, they germinate and infect the current year's needles. Initially, the fungus grows through the needle and into the twig without killing the needle. The following spring, infected needles die and turn a conspicuous red-brown. Infected branches take on a characteristic appearance, with current year's needles looking green and healthy while the one-year-old, infected needles are bright red-brown. Long, narrow, dull black fruiting bodies form on all surfaces of the dead needles and mature later in the summer, completing the infection cycle.

Fungal mycelium within the twigs spreads into the growing tips and buds, deforming future branch growth. As a result, infected branches have a broomed appearance similar to that caused by dwarf mistletoes. However, Elytroderma brooms are distinguished by several characteristics: the red-brown color of one-year-old needles in spring and early summer; fruiting bodies scattered over the needle surface; resinous, brown necrotic lesions in the inner bark of twigs and branches infected for three years or more; and, a lack of mistletoe shoots or basal cups.

Elytroderma disease kills one-year-old needles prematurely and deforms infected twigs and branches. Generally, pines are little affected if fewer than 40 percent of the twigs are infected. The disease seldom kills mature trees directly, but moderate-to-severe infection can predispose them to bark beetle attack. The disease is most severe on seedlings, saplings, and poles that are suppressed or have thin crowns. Disease outbreaks are uncommon, but once started, the disease can persist for many years, particularly in moist sites.

FIR ENGRAVER

The fir engraver (Scolytus ventralis) attacks both white and red fir in California. Trees ranging in size from large saplings to overmature sawtimber are susceptible. Attacks can cause patch-killing of cambium along the bole, top-kill, or tree death. Top-kill or death occur most often in firs that have been weakened by root disease, dwarf mistletoe, true mistletoe, overstocking, soil compaction, sunscald, logging injury, or drought. The fir engraver also breeds in slash and windthrown trees.

The fir engraver usually completes its life cycle in one year, sometimes two. Adults fly and bore into trees or green slash from June to September; larvae, pupae, and adults over-winter under the bark. Pitch tubes are not formed as they are with pine bark beetles; the usual evidence of attack is boring dust in bark crevices along the trunk and pitch streamers on the mid and upper bole. Trees colonized early in the summer may begin to fade by early fall, but those colonized later in the

year usually do not fade until the following spring or summer, often after the beetles have emerged.

WESTERN DWARF MISTLETOE

The dwarf mistletoes are serious forest diseases in much of the western United States, causing extensive growth loss and predisposing conifers to attack by bark beetles and other pathogens. Arceuthobium campylopodum, or western dwarf mistletoe, principally infects ponderosa and Jeffrey pines. Coulter and knobcone pines may be attacked when they grow in association with the principal hosts, but sugar pine is not susceptible.

Dwarf mistletoes are flowering plants that require a living host, from which they obtain most of their nutrients and all of their minerals and water. They spread by means of sticky seeds that are forcibly discharged from the plants in the fall, and adhere to whatever they contact. If a seed lands on a host needle or twig, it remains there over winter; the following spring it germinates, and the radicle penetrates the host. The parasite develops a root-like endophytic system in the inner bark and outer sapwood, and produces aerial shoots within 2-4 years after initial infection. Another 2-4 years elapse before seed are produced.

The spread of dwarf mistletoe is limited to the distance the seed travel, which from overstory to understory is usually 20-60 feet; with the aid of wind, seed may be carried as far as 100 feet. A rule of thumb is that dwarf mistletoes can spread a horizontal distance equal to the height of the plants in an infected tree. Because of various limits to spread and the long life cycle, the actual spread rate through an even-aged stand is usually 1-2 feet per year. Vertical spread through a tree crown is about 3-4 inches per year.

Dwarf mistletoe impact is influenced significantly by host vigor; slow-growing trees succumb more rapidly than thrifty ones, and dense, stagnated stands are especially vulnerable. Long-established infections of A. campylopodum can lead to witches' brooms (abnormal proliferations of twigs that appear as clustered masses of foliage); these are usually most pronounced in the lower branches, and eventually lead to the decline of the upper crown.

WESTERN PINE BEETLE

Dendroctonus brevicomis attacks ponderosa and Coulter pines. Beetles favor overmature trees, windfalls, and trees stressed by root disease, drought, dwarf mistletoe, overstocking, excessive moisture, fires, or any combination of these. Widespread stress can result in conditions favorable to population outbreaks. During these periods, apparently vigorous trees of all ages may be attacked and killed, although pines smaller than six inches dbh are seldom attacked.

Western pine beetle produces two-to-three generations per year in the southern Sierra Nevada. Beetle flight and subsequent attacks start in late spring or early summer, and continue until the return of cold weather. Initial attacks on standing trees occur about mid-bole and subsequent attacks fill in above and below. Inconspicuous pitch tubes and red boring dust are indications of success in overcoming a tree. Egg galleries under the bark cross and recross each other in a maze-like pattern unlike that of any other major western bark beetle.

WHITE FIR TRUE MISTLETOE

White fir mistletoe, Phoradendron bolleanum ssp. pauciflorum, is a true mistletoe having small, green leaves and round, white berries. It can only survive in living white fir tissues, principally as a **water parasite** utilizing water and minerals from the host. In California, it is limited geographically to the Sierra Nevada south of Interstate 80, and to the mountains of southern California.

This pest is spread mainly by birds, including robins, bluebirds, thrushes, phainopeplas, and cedar waxwings. Birds feed on the berries, digest their pulp, and excrete the living seed, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect host tissues.

Young or small trees are seldom infected by white fir mistletoe. In nearly all cases, initial infection occurs on the branches of larger or older trees because birds prefer to perch in their tops. Severe buildup of mistletoe often occurs in an already-infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

Heavily infected trees are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attacks by insects and often die during drought or other periods of stress. Severe infection of white fir can result in top-kill in combination with the fir engraver (Scolytus ventralis). Branches and tree tops heavily-laden with true mistletoe often break during wind storms, increasing the hazard to people and property in campgrounds and other developed sites.

White fir mistletoe is recognized by the clumps of mistletoe foliage in the tree. These mistletoe plants are usually in the tops of larger, older trees. With severe infections, virtually all of the tree's foliage may be replaced by mistletoe plants. Dead spike tops are common in white fir stands heavily infected by this parasite.